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ORIGINAL ARTICLE

# Use of palm fronds as shaded cover for evaporation reduction to improve water storage efficiency

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**Abstract** Water bodies in arid surroundings can be subject to high evaporation losses due to oasis effect. Evaporation raises the storage requirements of water bodies and lowers the yield. Covering of water bodies can help in reducing evaporation. The work presented in this study aims at investigating the use of palm fronds as shaded cover for the reduction of evaporation from the open water surface so as to increase the storage efficiency. The material used for cover was locally available palm fronds which are a massive agricultural waste and environmental friendly by-product in Saudi Arabia. Pan evaporimeters were used in the present study. One pan was covered like a shade made of palm fronds, which were tied up on mesh wiring while the other was kept without any cover. Initially a single layer of cover was used as shaded cover which was replaced by a cover of two layers of palm fronds in order to see the effect of thickness of cover on overall evaporation. It was observed that the average reduction in evaporation in the covered pan (with single layer of cover) was about 47% as compared to the evaporation from the open pan. However, the average reduction in evaporation in the covered pan (with double layer of cover) was about 58% as compared to the evaporation from the open pan.



## 1. Introduction

Water is the most precious natural resource in the world, especially in Saudi Arabia with arid climate and limited resources of surface water. Evaporation losses from small reservoirs affect their water storage efficiency. Evaporation from open water bodies such as wetlands, reservoirs and lakes often represents the largest loss in their local hydrological budget, yet its quantification still continues to be a theoretical and practical challenge in surface hydrology. Water bodies in arid surroundings can be subject to high evaporation losses due to the oasis effect. These high rates are due to energy advection, or extra energy input from the dry surroundings. Evaporation raises the storage requirements of water bodies and lowers the yield. Rate of evaporation from open water surfaces varies with the temperature or vapour pressure of the water and the air in contact with it, and further more the wind speed, barometric pressure and water quality. The annual rate of evaporation in Saudi Arabia is 3000 mm. Natural evaporation takes place by the exchange of water molecules between air and a free water surface (Ikweiri et al., 2008). This water surface could be a lake, pond or river. In the present study a Pan evaporimeter was used as a water surface. A Pan evaporimeter is a stan-

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dard evaporation pan based on the US Class A pan, originally developed by the US Weather Bureau.

Covering of water bodies can help in reducing evaporation. There are many materials; chemicals and physical covers which can effectively and efficiently reduce the evaporation from open water bodies. Such types of materials are used to suit the local climatic conditions and availability as well. There has been an increased focus on evaporation control techniques which can be applied to water storage due to severe drought conditions in many parts of the world (Anonymous, 2003). In a similar study Barnes (1993) found that monolayer is potentially most effective in conditions where the rate of evaporation is high. The study by Alvarez et al. (2006) on different types of shading meshes reveals that the shading of pan induced a significant decrease of the daily evaporation rate, ranging from 50% for the aluminized screen to near 80% for the coloured-polyethylene meshes.

Craig et al. (2007) observed that the use of physical cover was able to reduce evaporation substantially, they suggested that these types of covers would be more effective with small reservoirs (less than 10 ha in size). However the physical covers can also be used for large reservoirs but it could be uneconomical.

Recent study done by Al-Hassoun et al. (2009) on impounding reservoirs found that the average reduction in evaporation using the floating cover made up of palm leaves was 63% for the fully covered pool while for the half covered pool it was 26% only.

Palm tree is considered to be one of the most important commercial crops widely distributed across the Saudi Arabia capable of withstanding extremely hot weather conditions of the arid region (Al-Juruf et al., 1988). The number of trees in the Kingdom is estimated to be over 21 million. These trees are estimated to yield about 210,000 tons of fronds (Al Gassim Dates Factory, 2011). Every year many palm trees have to be pruned (about three million trees a year), moreover this amount is evenly distributed all over the country which makes it particularly attractive for its use in the development or control project which benefits every part of the country. After pruning, fronds are considered as disposed waste.

Present study proposes the use of Palm fronds as shaded cover for the reduction of evaporation from the open water surface.

## 2. Materials and methods

### 2.1. Experimental setup

Pan evaporimeters were used in the present study. One advantage of evaporation pan is that they incorporate all possible physical effects (Roderick et al., 2007). A Pan evaporimeter is a standard evaporation pan based on the US Class A pan, originally developed by the US Weather Bureau. A US Class A pan is a circular tub of 1210 mm internal diameter; 250 mm deep and is constructed of one millimetre thick galvanised steel sheet. The evaporation pan was installed, set and leveled on the roof of the department of Civil Engineering building, King Saud University, away from any obstacles which may obstruct a natural air flow around the pan, thus representing open water in an open area. Pans were always covered with open mesh wiring to stop animals and birds from drinking or using water.

### 2.2. Material of pan cover

The material used for cover was locally available palm fronds which are a massive agriculture waste and environmental friendly by-product in Saudi Arabia One pan was covered like a shade made of palm fronds (Fig. 1), which were tied up on mesh wiring while the other was kept without any cover (Fig. 2). Shaded cover reduces the energy available for evaporation; reduces wind action over the water surface and traps humid air under the cover, all factors that contribute to evaporation. Initially a single layer of cover (1.9 mm thick) made of palm frond was used as shaded cover which was replaced by a cover of two layers of palm fronds (3.8 mm thickness) after three months in order to see the effect of thickness of cover on overall evaporation.

### 2.3. Recording of data

Evaporation was measured by measuring changes in water level in the pan. This was done manually with point gauge. The data were recorded at 9:30 am and 2:30 pm daily except weekends (Thursday and Friday). The amount of evaporation is a

**Figure 1** Evaporation pan covered with palm fronds.

**Figure 2** Evaporation pan without cover.

function of temperature, humidity, wind and other ambient conditions. In order to relate evaporation to wind current or expected conditions, data of continuous ambient temperature as well as the amount of water passed with evaporation were recorded with the help of a nearby weather station. Measurements started from 12/10/2010. Water was added into the Pans to substitute the evaporation when water level in the pan was dropped to 17 cm. All data were subjected to statistical analysis of mean and standard deviation.

## 3. Results and discussion

A large amount of data were collected during the study period starting from October 2010 to June 2011, but only the most important data and results have been presented herein. These data include measurement of water depth in pans, evaporation and air temperature. Recorded data were summarized as monthly average and presented in Table 1. Relation between measured evaporation and ambient air temperature for the period of nine months (October 2010 to June 2011) is shown by Fig. 3. It is clear from the figure that evaporation from the pan has a direct relation to the ambient air temperature; month with higher ambient air temperature has recorded a higher value of evaporation.

Fig. 4 shows a comparison of measured evaporation from the two pans with average ambient air temperature. The result indicates a significant difference in evaporation from the open pan compared to evaporation from the covered pan. This confirms the feasibility of using the fronds in evaporation reduction because they provide a barrier between water and atmosphere. This barrier directly reduces the impact of solar radiation and ambient temperature.

The experimental observations revealed that the evaporation rate was directly affected by the ambient temperature as the rate of evaporation was higher during the day time (when ambient temperature was higher) while it was less or minimum in the evening and night.

Fig. 5 represents the overall percentage reduction in evaporation using single layer of palm fronds as cover and double layer of cover. It was observed that the average reduction in evaporation in the covered pan (with single layer of cover) was about 47% as compared to the evaporation from the open pan. The period of this observation was October 2010 to December 2010. However, the average reduction in

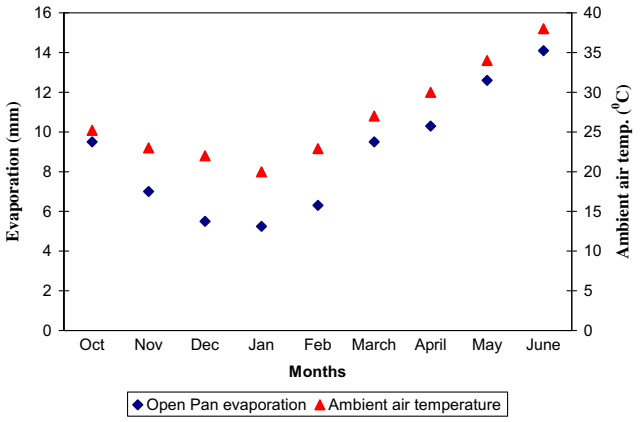


**Figure 3** Evaporation versus average ambient air temperature.

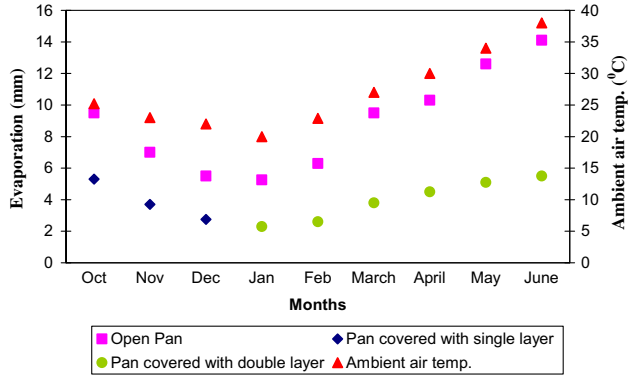


**Figure 4** Evaporation from two pans versus average ambient air temperature.

evaporation in the covered pan (with double layer of cover) was about 58% as compared to evaporation from the open pan. The period of this observation was January 2011 to June 2011. This result indicates that there was a further reduction in evaporation when the single layer of cover was changed with the double layer of cover, but this change was only 19% which is not very significant as it will increase the cost of covering. However, the amount of evaporation depends on water surface area thus percentage reduction in evaporation would depend

**Table 1** Daily average data of ambient air temperature, evaporation from open and covered pans.

| Month | Evaporation (daily avg.) from open pan (mm) | Ambient air temperature (daily avg.) (°C) | Evaporation (daily avg.) from the pan with single layer cover (mm) | Evaporation (daily avg.) from the pan with double layer cover (mm) | Relative difference in evaporation (% reduction) |
|---|---|---|---|---|---|
| October | 9.6 ± 0.15 | 25.2 ± 0.17 | 5.3 ± 0.09 | – | 44.8 ± 0.15 |
| November | 7.0 ± 0.17 | 23.0 ± 0.16 | 3.7 ± 0.13 | – | 47.1 ± 0.16 |
| December | 5.5 ± 0.22 | 22.0 ± 0.19 | 2.8 ± 0.10 | – | 50.0 ± 0.17 |
| January | 5.3 ± 0.14 | 20.0 ± 0.14 | – | 2.3 ± 0.11 | 56.2 ± 0.15 |
| February | 6.3 ± 0.12 | 22.9 ± 0.15 | – | 2.6 ± 0.12 | 58.7 ± 0.22 |
| March | 9.5 ± 0.11 | 27.0 ± 0.19 | – | 3.8 ± 0.09 | 60.0 ± 0.13 |
| April | 10.3 ± 0.13 | 30.0 ± 0.24 | – | 4.5 ± 0.12 | 56.3 ± 0.15 |
| May | 12.6 ± 0.11 | 34.0 ± 0.16 | – | 5.1 ± 0.11 | 59.5 ± 0.13 |
| June | 14.1 ± 0.11 | 38.0 ± 0.17 | – | 5.5 ± 0.13 | 61.0 ± 0.16 |

Each value is the mean ± standard deviation ($n$ = 22).

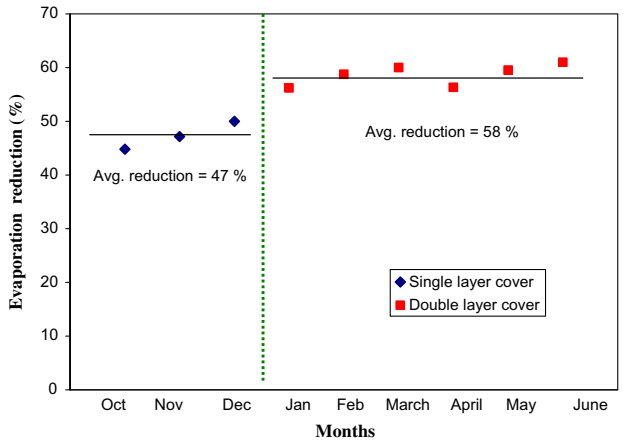


**Figure 5** Percentage reduction in evaporation using palm fronds as cover.

upon the cover type and the size of the surface (Cooley, 1983). A study by Bean and Florey (1968) reveals that the evaporation reduction with a partial cover of surface of lake Hefiner, USA was 58%. Recent study by Al-Hassoun et al. (2011) shows evaporation reduction of 55% from the pool using a fully floating cover made of palm leaves, further they found that the percentage reduction in evaporation is directly proportional to covered water surface area. The results of the present study are in full agreement with the results obtained by previous investigators.

## 4. Conclusion

Covers made of palm fronds were used to reduce the evaporation from the pan. In the entire nine months of the investigation period, initially one pan was covered with a single layer cover of palm fronds while after three months from the start another layer of cover was placed over the pan making it double layer cover. Results obtained from the experimental data revealed that about 47% reduction in evaporation can be achieved by using single layer of cover. On the other hand the percentage reduction in evaporation was found to be about 58% by the use of double layer cover which is approximately 19% higher as compared to percentage evaporation reduction by use of single layer cover.

Palm tree is considered to be one of the most important commercial crops and is widely distributed across the country. Palm fronds and leaves are considered as disposed waste after pruning. Therefore, it is recommended to use palm fronds as cover for open water surfaces to reduce evaporation as it is a good use of disposed waste, is environmental friendly and is capable of withstanding extremely hot weather conditions of the arid region.

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## References

Al Gassim Dates Factory <http://www.gassimdates.com/index.php?action=pages&id=28>.

Al-Hassoun, S.A., Mohammed, T.A., Nurdin, J., 2009. Evaporation reduction from impounding reservoirs in arid areas using palm leaves. J. Eng. Appl. Sci. 4, 247–250.

Al-Hassoun, S.A., AlShaikh, A.A., Al Rehaili, A.M., Misbahuddin, M., 2011. Effectiveness of using palm fronds in reducing water evaporation. Can. J. Civil Eng. 38 (10), 1170–1174, 10.1139/l11-071.

Al-Juruf, R.S., Ahmed, F.A., Alam, I.A., 1988. Development of heat insulating material using date palm leaves. J. Therm. Insulation 11, 158–159.

Alvarez, M.V., Baille, A., Molina-Martinez, J.M., Gonzalez-Real, M.M., 2006. Efficiency of shading materials in reducing evaporation from free water surfaces. J. Agric. Water Manag. 84, 229–239.

Anonymous, 2003. Department of Natural Resources and Mines. Methods for Reducing Evaporation from Storages Used for Urban Water Supplies, Final Report, 41/12219/67346.

Barnes, G.T., 1993. Optimum conditions for evaporation control by monolayers. J. Hydrol. 145, 165–173.

Bean, B.R., Florey, Q.L., 1968. A field study of the effectiveness of fatty alcohol mixtures as evaporation reducing monomolecular films. J. Water Resour. Res. 4, 206–208.

Cooley, K.R., 1983. Evaporation reduction: summary of long-term tank studies. J. Irrig. Drainage Div. ASCE 109, 89–98.

Craig, I., Aravinthan, V., Joseph, P., Baili, C., Beswick, A., 2007. Evaporation, seepage and water quality management in storage dams: a review of research methods. J. Environ. Health 7, 84–97.

Ikweiri, F.S., Gabril, H., Jahawi, M., Almatrdi, Y., 2008. Evaluating the evaporation water loss from the Omar Muktar open water reservoir. In: Twelfth International Water Technology Conference, IWTC, Alexandria, Egypt, pp. 893–899.

Roderick, M.L., Rotstayn, L.D., Farquhar, G.D., Hobbins, M.T., 2007. On the attribution of changing pan evaporation. Geophys. Res. Lett. 34, L17403. http://dx.doi.org/10.1029/2007GL031166.